

Author : DebasishDas

[SUNDIALS TO TELL THE TIMES OF PRAYERS IN THE MOSQUES OF INDIA](#)

January 1, 2018

About

It is said that Delhi has almost 1400 historical monuments.. scattered remnants of layers of history, some refer it as a city of 7 cities, some 11 cities, some even more. So, even one is to explore one monument every single day, it will take almost 4 years to cover them.

Narratives on Delhi's historical monuments are aplenty: from amateur writers penning down their experiences, to experts and archaeologists deliberating on historic structures. Similarly, such books in the English language have started appearing from as early as the late 18th century by the British that were the earliest translation of Persian texts. Period wise, we have books on all of Delhi's seven cities (some say the city has 15 or more such cities buried in its bosom) between their covers, some focus on one of the cities, some are coffee-table books, some attempt to create easy-to-follow guide-books for the monuments, etc.

While going through the vast collection of these valuable works, I found the need to tell the city's forgotten stories, and weave them around the lesser-known monuments and structures lying scattered around the city. After all, Delhi is not a mere necropolis, as may be perceived by the un-initiated.

Each of these broken and dilapidated monuments speak of untold stories, and without that context, they can hardly make a connection, however beautifully their architectural style and building plan is explained.

My blog is, therefore, to combine actual on-site inspection of these sites, with interesting and insightful anecdotes of the historical personalities involved, and prepare essays with photographs and words that will attempt to offer a fresh angle to look at the city's history. I have taken references from a wide variety of literature available – both online, and paper-format books.

It is not an attempt to be a guide or to simplify the city's heritage: it is for people who want to lose themselves again and again in the narrow passages of history.

If you have any comments, please do share it. You can contact me as well at debasish7777@gmail.com.

Thank you once again for stopping by and going through my articles...



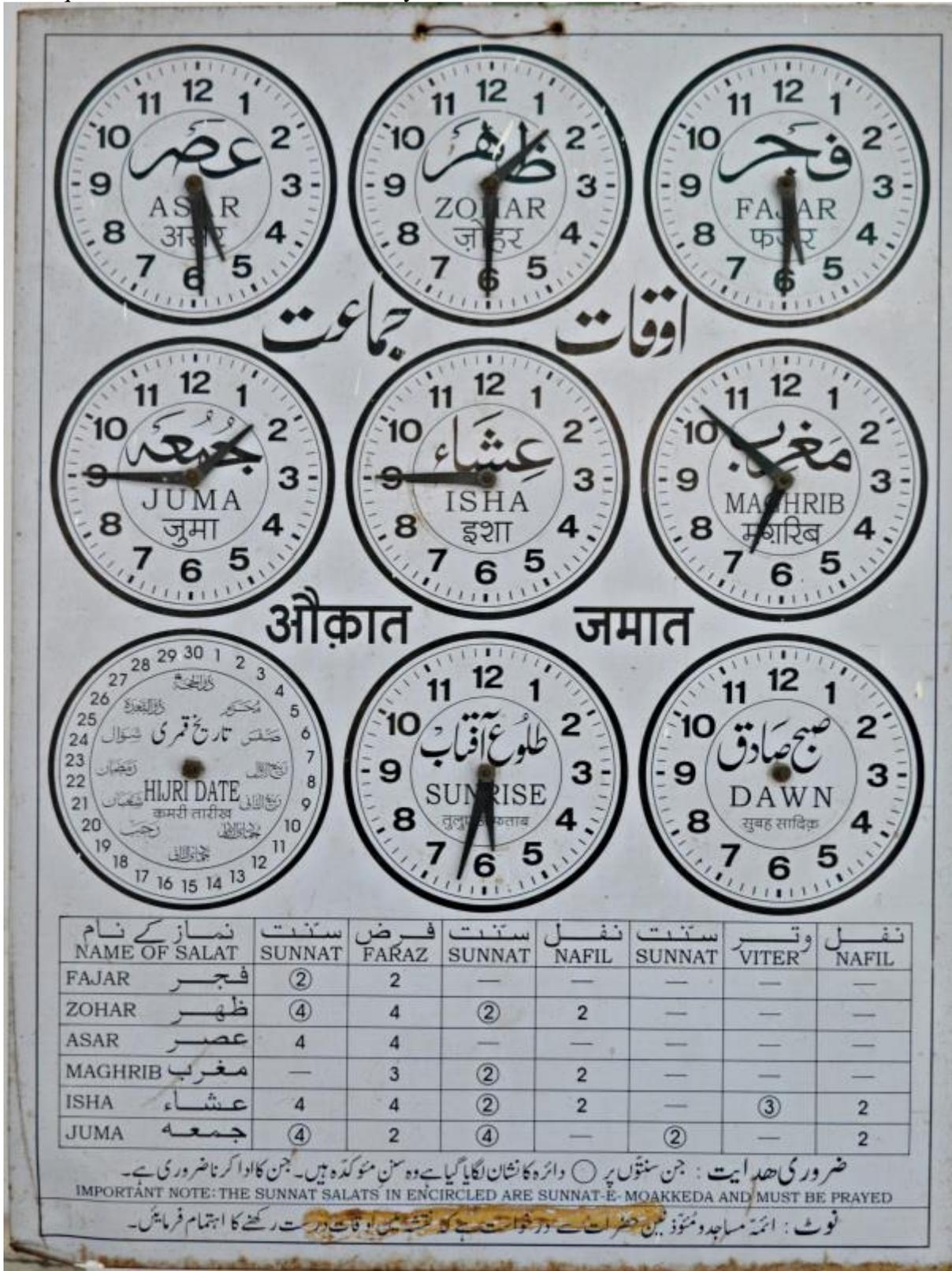
[My Heritage Walks](#)

SUNDIALS TO TELL THE TIMES OF PRAYERS IN THE MOSQUES OF INDIA

by [DebasishDas January 1, 2018](#)

When Prof. S. R. Sarma, an eminent authority on Indian astronomical instruments, requested me some months ago for photos of the sundial in the Jama Masjid, little did I imagine that I would be in for an exciting journey of discovery. Soon I found myself embarked on a sundial hunting spree: from Delhi to Hyderabad, then to Mysore, to Pulicat in the far south and to Jaipur and Western U.P. Every new sundial that I came across was designed differently and required fresh understanding to decode its curves and inscriptions. Like learning a new language, slowly I began to appreciate this fine science of antiquity, helped much through my correspondence with Prof. Sarma over last many months and from his recently updated unique catalogue on Indian instruments, called ‘A Descriptive Catalogue of Indian Astronomical Instruments.’

For conducting this study, while I could take detailed photographs from Delhi, namely at Jama Masjid and Fatehpuri Masjid, I had to seek support of friends for sites in other cities. My sincere thanks to my colleagues and friends, who had to take out precious time to visit remote places. Here is the list of friends who did the actual exploration and took photos. While photographs from Hyderabad, Pulicat, Mysore/Srirangapatna were taken by Subbarao K, Premnath M.S., and Ejaz Ahmed respectively; those from Ghazipur and Nauli were taken by Dr. Nadeem Adhami and Gurdeep Singh respectively. Photographs of the sundial from Khanqah of Maulana Ziauddin Ziai at Jaipur were shared by Syed Ziauddin Ziai, and that from



(Clocks showing Islamic Prayer Times at Sunheri Masjid, Chandni Chowk, Delhi)

It was an exhilarating journey, but also a sad one because many of the sundials are deteriorating through sheer neglect. Though originally designed to tell prayer times in mosques, with the availability today of more accurate watches, these antique sundials do not serve any practical purpose. However, these are valuable historical documents and deserve proper preservation.

Before describing the various sundials, a few words are in order to explain the mandatory prayers in Islam and their relation to the sundials.

For Muslims, the day commences at sunset and lasts until the next sunset. The five mandatory prayers in such a day are: *Maghrib*, or sunset; *Isha*, or nightfall; *Fajr*, or daybreak; *Zuhr*, or Midday; *‘asr*, or afternoon.

The times of these prayers, in particular those of the two daytime prayers, *zuhr* and *‘asr* are astronomically defined and can be indicated by a sundial. *Zuhr* is said to begin when the shadow of the gnomon begins to lengthen after reaching the minimum at noon. The time to offer *‘asr* prayer starts when the shadow's length (s) equals the sum of noon-time shadow length (n) and the gnomon's height (g); it lasts until the shadow length becomes equal to the noon-time shadow length plus twice the gnomon's height. These two time limits are called *‘asr-i-awwal* and *‘asr-i-sani*. Simply put,

The first limit (*‘asr-i-awwal*) occurs when $s = n + g$

And the second (*‘asr-i-sani*) occurs when $s = n + 2g$.

For indicating both these time-limits, the sundial is engraved with two special curves. Due to variation in the sun's declination every day at every latitude, the times of commencement and conclusion of *‘asr* vary from day to day.

To facilitate the preparation of the sundial, Muslim astronomers prepared detailed tables marking the times for each of the 365 days of the year and for every degree of latitude of the inhabited world. With the help of these tables, the two *‘asr* curves could easily be drawn on the sundials.

Furthermore, Muslims are required to offer prayers while facing the Kaaba in Mecca; and the *mihrab* in mosques are aligned towards Mecca. The angle of this sacred direction is called *Qibla*. Again, Muslim astronomers compiled detailed tables of spherical trigonometry for calculating the *Qibla* from every place in the inhabited world.

Scholars are of the opinion that these two religious requirements caused the development of mathematical astronomy in the Islamic world. One of important features of Islamic astronomy are the exhaustive tables mentioned above, which are called *zij*. There are said to be hundreds of *zijas* extant, which include tables for spherical astronomy and trigonometry functions, star tables and many others. In India also, Sawai Jai Singh of Amber wrote his famous *Zij-i Muhammad Shahi* in the eighteenth century.

1.0 Jama Masjid, Delhi

Let us begin the journey with the magnificent Jama Masjid built by Mughal Emperor Shah Jahan. As one enters the mosque through the eastern gate, which was originally meant exclusively for the emperor and the high nobility, one is overwhelmed so much by the sight of the great domes beyond the vast front court that one does not notice the small features like sundials. I had to ask many people until I could locate the sundials in the south-east corner, close to the outer boundary of the front court.



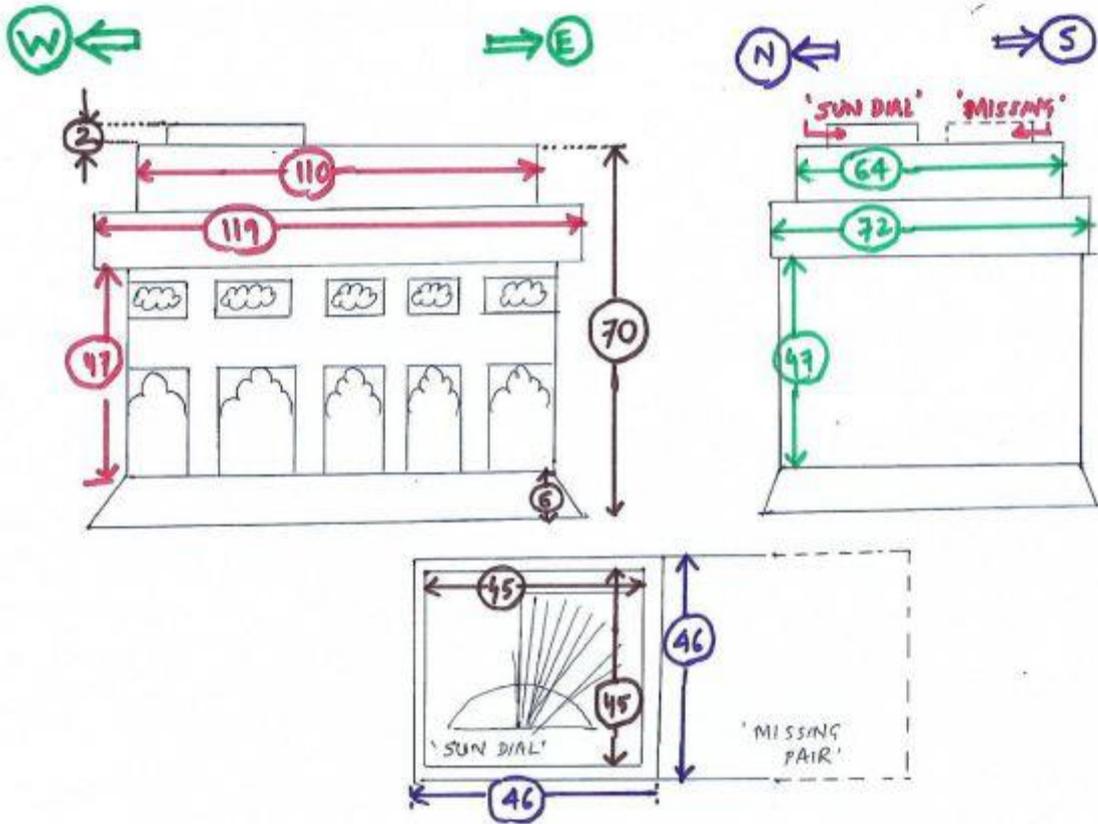
(Jama Masjid, Delhi.)

1.1 Sundials in SE

In the south-east corner of the front court, there are two pedestals: a round one with a missing top and a rectangular pedestal with a sundial occupying half of it: the other half is empty. The sundial is engraved on a 46 x 46 cm marble slab. The marble slab is 2 cm thick and sits on a 70-cm high pedestal. Its inscriptions are heavily damaged. On the lower half is engraved a semi-circular dial to show time from 6 am through 6 pm. Diameter of the dial is 33.5 cm. The dial is marked with hour marks from 8 am to 12 noon on the left and from 1 pm to 5 pm on its right in Roman numerals. But the gnomon is missing; it would have been in the shape of a right-angled triangle, the angle between the base and hypotenuse being equal to the latitude of Delhi; then the hypotenuse would point to the celestial north pole.

A basic horizontal sundial consists of two parts: the gnomon which is a vertical wedge that casts a shadow and the dial plate where the hour markings are inscribed. The gnomon is raised at an angle equal to the latitude of the place, so it is location specific and a sundial designed for one city is useless for another city on a different latitude. The point where the north axis cuts the circumference of the dial plate is marked 12 p.m. Points on its left are marked for morning hours till sunrise, i.e. 11, 10, 9, 8, 7, 6. Similarly afternoon hours till sunset are marked on its right, i.e. 1, 2, 3, 4, 5, 6.

In the Jama Masjid dial, four lines from the centre to hour markings of 12 noon to 4 pm are extended upwards to enclose a rectangle with 18 concentric quarter circles. The quarter circles are to measure the lengths of the gnomon's shadow. They are numbered from 7 to 23. These quarter circles are super-imposed by two curves which indicate the starting time and the ending time of afternoon prayer time '*asr*'.



(Elevation and plan of the sundial pedestal at Jama Masjid, Delhi. All measurements are in cm)

For Delhi, start of the 'asr' ('asr-i-avval) is calculated to range from 14:51 pm to 15:32 pm. End of the 'asr' ('asr-i-sani) corresponds to a range from 16:22 pm to 16:50 pm for Delhi's altitude.



(The Delhi Jama Masjid Sundial and its missing companion)

At the bottom of the dial is written 'Sun Dial' in English and 'Dhoop Ghari' in Urdu. The inscriptions state that the sundial was made by Hafiz Anwar Ali Siddiqi of Rohtak under the supervision of Sayyid Ahmed,

the Imam of the congregational mosque at Ajmer. The top line on the dial reads '*asr ghadi Dihli ard balad 28 darjah 39 daqiqah*' (Asr Clock for the city of Delhi at the latitude of 28 degrees and 39 minutes).

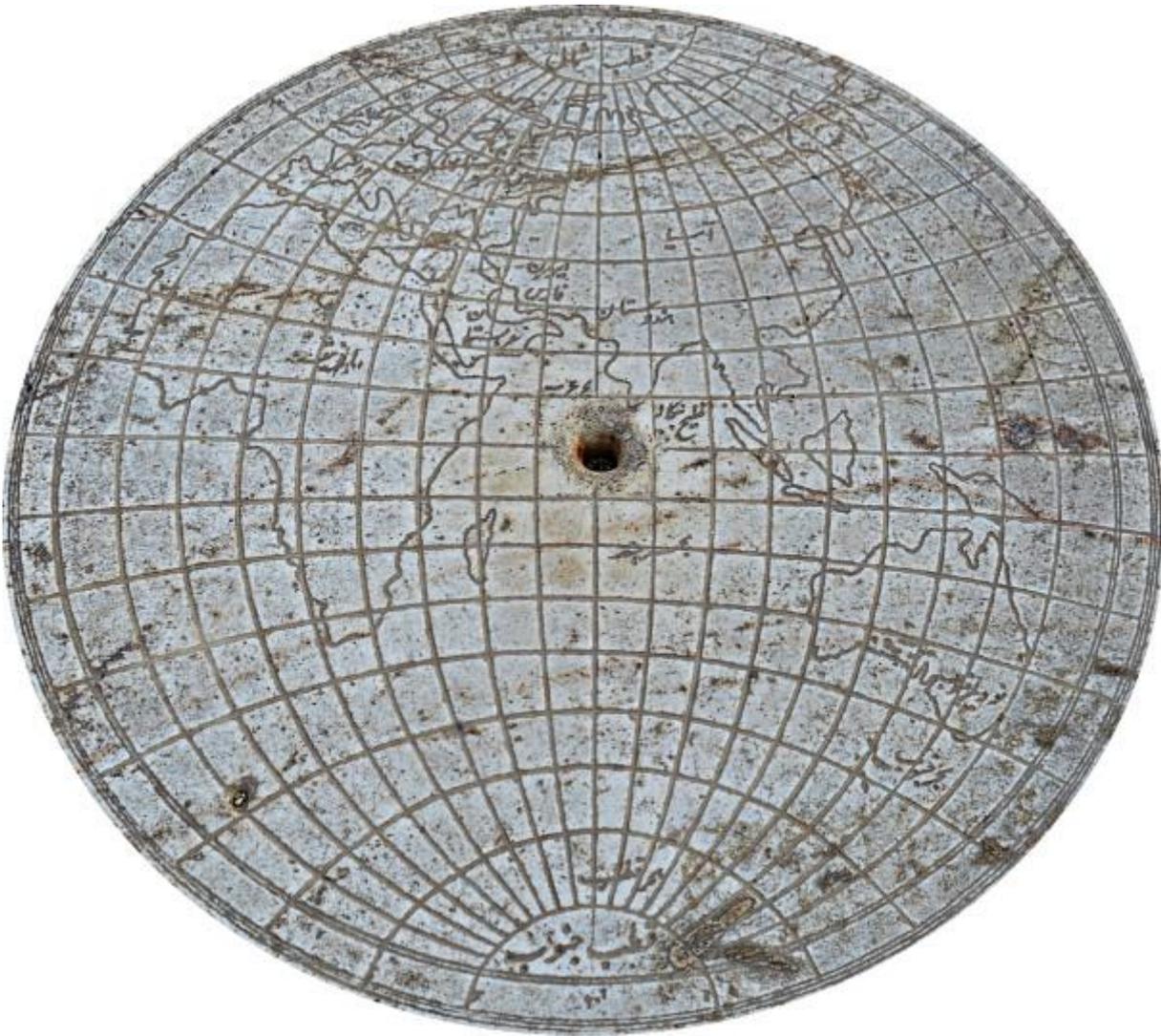
Unfortunately, the companion slab to the sundial is missing. Similarly, the top of a circular pillar nearby is also long lost. Now it is impossible to know when they were removed and by whom.

1.2 World-map in NE of the Jama Masjid, Delhi

Prof. Sarma also mentioned a world-map engraved on a stone slab. This one is situated on the other side of the eastern gate, i.e., in the north-eastern corner. It is engraved on a marble slab (55 x 58 cm) which is set up on a 112-cm high pedestal. Due to its tall height, it is not so easy to take a clear image of the map. I had to ask someone to lift me up so that I could take few shots with my shaking hands.

The world map is inscribed inside a circle in an old style called 'Lambert azimuthal equal-area projection' as against the modern maps which are based on 'Mercator Projection'. Moreover, longitudes are arranged in such a manner that India is nearly at the centre of the map. There is a large hole at the centre.

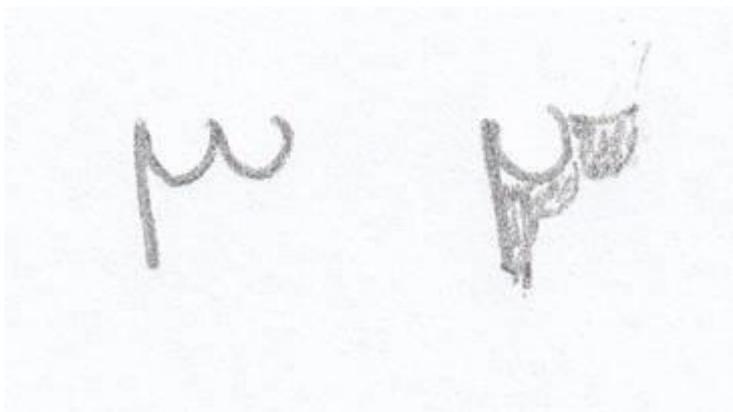
The long inscription below the map reads: "The figure of the earth and the southern and northern climates [with respect to] the equator with the lines of longitude and latitude of the cities in the reign of Muhammad Akbar Shah Badshah Ghazi, [in the] year 1247 Hijri (1831-32), by order of the prince Muhammad Salim Bahadur Shah, Qazi Shuja al-Din Ali-Khan Ghazi... built and left as a memorial (*yaadgaar*)."



(The world map at the N-E courtyard of Jama Masjid, Delhi.)

Prince Muhammad Salim Bahadur Shah, also known as Mirza Salim, is a younger brother of the last Mughal Emperor Bahadur Shah Zafar. He must have commissioned Qazi Shuja al-Din Ali-Khan Ghazi to prepare the world-map. The Qazi must have copied this India-centric map from an English atlas, because here Australia is labelled as '*naw wilz janub*' literally meaning 'New South Wales', the name of the first British colony in Australia. The outline of peninsular India is also not well formed. Other regions that are labelled on the map include *qutb shamal* (North Pole), *frans* (France), *fars* (Persia), *bahr qutb* (polar sea or Antarctic Ocean), *qutb janub* (South Pole), and so on.

The date inscribed on the sundial is not clearly decipherable. While it looks as 1345 Hizri in the first look, it needs a closer inspection. The second digit seems as if it is '3', that is a vertical stroke to which two half circles are joined. But if it is enlarged, the second half circle can be seen not as sharply defined as the first one. Rather it is just the expansion of the corrosion as shown in below pencil sketch. The third digit can be either 2 or 4, since the difference is not clearly visible. Therefore, the year is either 1225/1810-11 or 1245/1829-30, making it a contemporary of the world map (1831-32).



(Analysis of the digits inscribed on the sundial, courtesy Prof S R Sarma)

It can thereby be safely said that it must have been set up at the instance of Prince Mirza Salim. The Prince is also said to have made several important additions in the mosque such as the sandstone pulpit near the main entrance of mosque in 1829. It is therefore possible that he also commissioned the sundial (1819-20) and the world map (1831-32). It can be conjectured that the two missing slabs — one on a nearby circular pedestal, and another on the companion slab of the rectangular sundial — had two more astronomical instruments simultaneously set up by Mirza Salim.



(The circular pedestal could possibly have had some other astronomical instrument mounted on it)

What was engraved on the missing slab on the circular pedestal and on the one next to the sundial on the rectangular pedestal? Who commissioned them and when were they removed? More important, what was the purpose of setting up a world-map inside a mosque? One would rather expect a Mecca-centric map which shows the direction and the distance of *Qibla* in a mosque, but not an India-centric atlas. The world-map was said to have been erected as a memorial or *yaadgaar*. Which significant event of 1831-32 could have called for such a memorial? Who was the Qazi who prepared this world-map? What was held in the large hole at the centre of the map? Did it have a vertical gnomon and was it designed as some kind of a shadow-instrument?

1.3 Old Accounts of Delhi

We looked for answers to these and other queries in the old accounts of Delhi. But the sundial and the world-map are hardly mentioned anywhere. Indeed, it seems that these two artefacts had not yet been consciously analysed till Prof. S.R. Sarma's work earlier this year.

Gordon Hearn in his *Seven Cities of Delhi* (1928) remarks in passing: "On a pillar in the court is engraved an old map of the world." Carr Stephen in his *The Archaeology and Monumental Remains of Delhi* (1876) mentions that "In the year 1829, Mirza Salim, son of Akbar II, put up a sand-stone pulpit under the central

entrance of the mosque, the congregation being at time too large to take part in the prayers offered by the Imam inside the mosque” and “In the north-eastern corner of the court of the mosque is a plain sphere cut upon marble, giving a map of the world according to the common projection of the sphere.” Sir Syed Ahmed Khan, founder of Aligarh Muslim University, in his Urdu book *Asar ul-Sanadid* (1847) briefly mentions the sundial. A short translation by Fatima Quraishi published in the *Journal of Art Historiography* of 2012 has the lone sentence, “In the southern and eastern courtyard are clocks to indicate prayer times.” The mention of ‘clocks’ in plural indeed gives credence to our earlier conjecture that the two missing slabs might have had additional sundials on them.

The Jama Masjid was built by Shah Jahan between 1644 and 1656. The existing sundial was set up in 1819-20. Was there no earlier sundial in this mosque or elsewhere?

2. Mecca Masjid, Hyderabad

The oldest extant sundial is in the Mecca Masjid at Hyderabad. As one approaches the Char Minar from the Musi river, the mosque is just behind the Char Minar. It is situated at 17.36° N, 78.47° E and one of the largest mosques in India.

Prof. Sarma and his mentor Prof. David King saw and photographed the sundial in 1991. In Prof. Sarma’s photographs, the inscription on the sundial is not clearly visible; he requested for better photographs. I, in my turn, asked my Hyderabad-based colleague Subbarao, K., who promptly sent me several photographs. Therefore, our virtual journey went thither.

Muhammad Qali Qutb Shah commenced the construction of this mosque in 1616, but it was completed by the fifth ruler of Qutb Shahi dynasty, Muhammad Quli Qutb Shah, in 1694 under the orders of Aurangzeb. The mosque is so named because its central arch was constructed with the soil brought from Mecca. On its grandeur, Tavernier, the French traveller writes,

“It is about 50 years since they began to build a splendid pagoda in the town which will be the grandest in all India when it is completed. The size of the stone is the subject of special accomplishment, and that of a niche, which is its place for prayer, is an entire rock of such enormous size that they spent five years in quarrying it, and 500 to 600 men were employed continually on its work.”

It is here that we find the oldest sundial in India which is still extant in a mosque. The dial is a circular plate of 63.5-cm diameter mounted on a 122-cm pillar. At its centre is a hole that held the gnomon, now missing. The dial surface has undergone such erosion that few sentences can no longer be deciphered easily. Behind this unique sundial, the ornate domes of Nizamia Tibbia college can be seen in the distance.



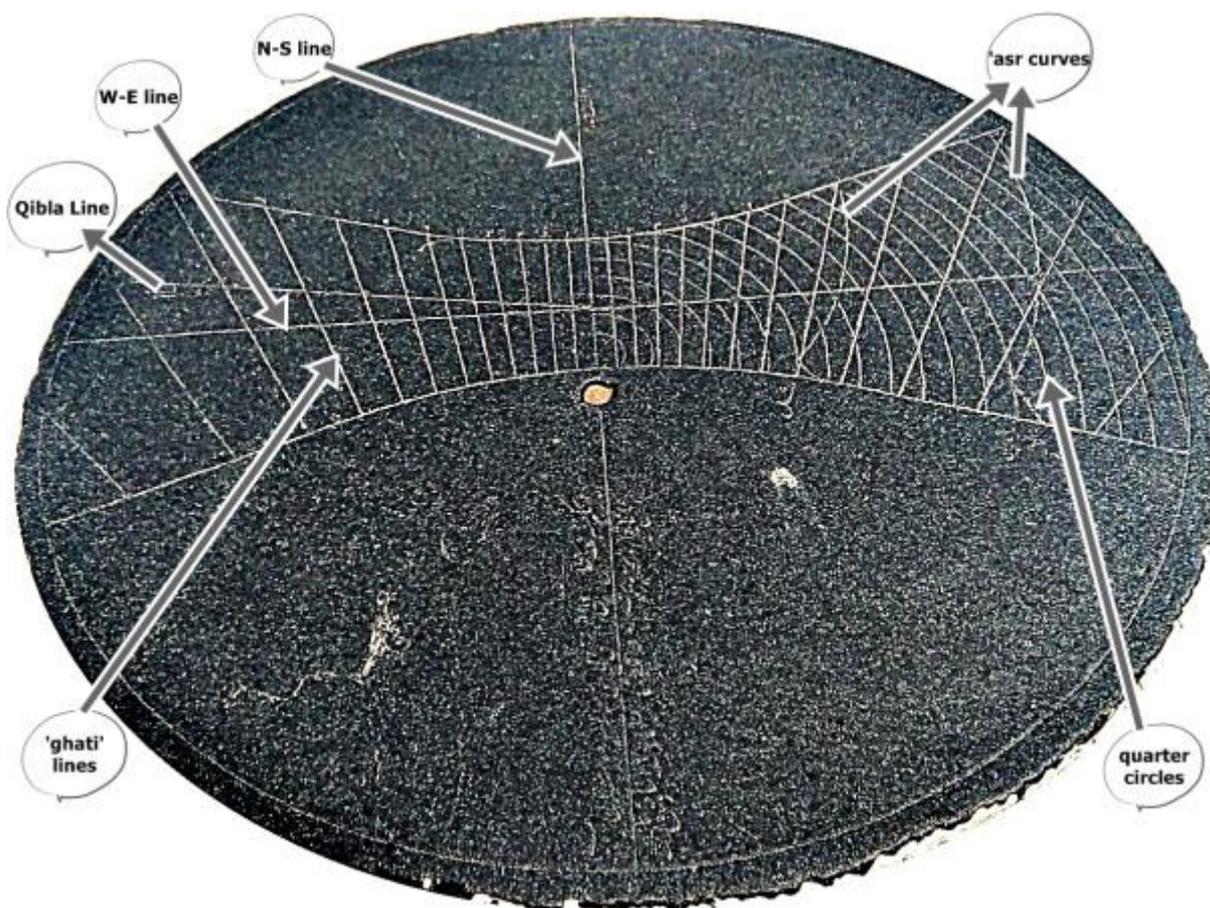
(The sundial and its pedestal at Mecca Masjid, Hyderabad. Photo courtesy: Subbarao K.)

The Hyderabad dial is a simplified version of dials using hyperbolic curves such as the world-renowned one at Umayyad Mosque in Damascus.

In this image, the vertical line represents the N-S line or the meridian while the horizontal line represents the W-E line. The lower hyperbola represents the summer solstice, the upper one denotes the winter solstice and the straight W-E line represent the equinoxes. The hour lines are marked on either side of meridian as a series of 10 straight lines, but they denote 'ghati' of 24 minutes each instead of 60-minute hours. So, the 10 lines cover a time span of 240 minutes or 4 hours on either side of the meridian, i.e. from 8 am to 12 noon on the left and from 12 noon to 4 pm on the right.

That this sundial is calibrated in the traditional Indian units of *ghatis* should not surprise us. When Muslim sultans established themselves in India, they adopted the local units of time such as the *ghati* and *pahar* for everyday common usage, reserving the 60-minute hours for astronomical purposes. Babur talks about this local units of time measurement. The *Ain-i-Akbari* has a description of a water clock with which *ghatis* were measured. Jahangir too records time in *ghatis* in his memoires. After the advent of the British, both Muslims and Hindus started using hours progressively.

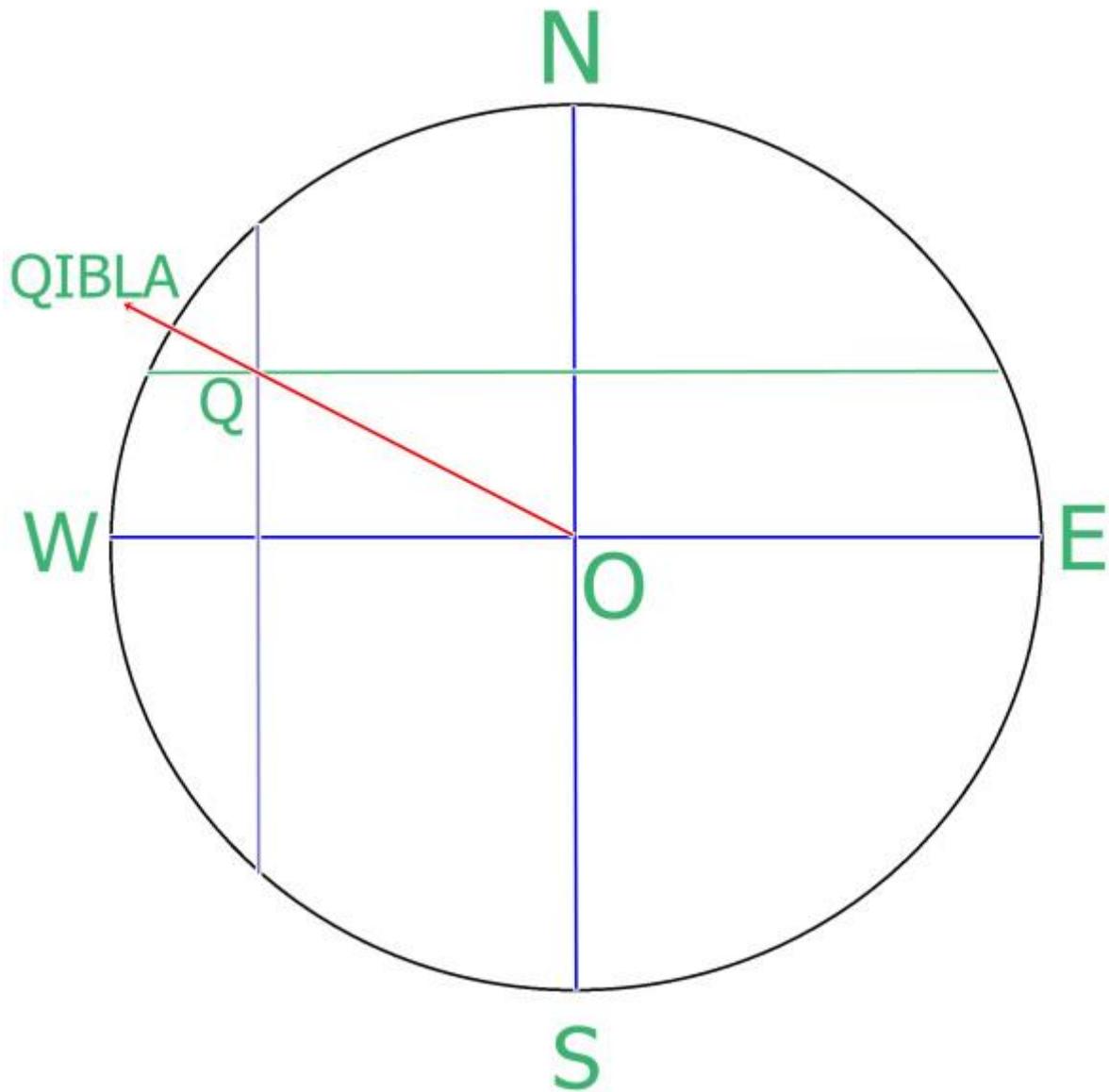
On the right, we can see broad sweeps of two large arcs, showing the times of beginning and end of 'asr. They are super-imposed on a grid of 20 concentric quarter circles to measure shadow length of the gnomon.



(Mecca Masjid dial with two distinctive hyperbolas representing the two solstices. Photo courtesy: Subbarao K.)

A single straight line shoots off from the centre of the dial towards west, showing the direction of *Qibla*. In fact, out of all sundials still extant in Indian mosques, only the Hyderabad sundial is the unique in the sense

it has a *Qibla* line. Calculating on the basis of longitudinal and latitude differences between Hyderabad and Mecca, the qibla line is drawn at 77.27 degrees with respect to the N-S line, or at about 23 degrees off the West. It is often considered that direction to Mecca in India is always towards West, but exact mathematical calculations based on longitude and latitude offsets of the location with respect to that of Mecca give the accurate angle of the qibla.



(An approximate method to find the qibla was shown by al-Battani as given in David A. King's 'Astronomy and Islamic society: Qibla, gnomonics and timekeeping')

The simplest and therefore an approximate method for determining the *Qibla* postulated by al-Battani was a graphical one. On a circle laid on a horizontal plane, draw two diameters along N-S and E-W directions that intersect at the centre O. Calculate the longitude difference between the current location and Mecca (say L), and draw a parallel line to N-S with the circle cut with the angle L. Similarly find the latitude difference between the location and that of Mecca (say M). Draw a line parallel to E-W at an angular distance of M. Let the intersect point of these two lines be called Q. Then OQ is the qibla.

An inscription towards the North says '*nisf al-nahar*' (mid-day). Towards the South, two lines of inscriptions read as:

‘By the order of His Majesty...Abu al-Muzaffar Muhy al-Din Muhammad Alamgir Badshah. Made by ...Mir Qasim for the latitude of the city of Hyderabad in the blessed regnal year 36...’

While Hyderabad can boast to have the oldest sundial existing in India, to find one of later varieties, we need to travel to the eastern part of the country, to the city of Patna.

3. Khanqah Emadia, Patna



(The only image of Emadia Khanqah sundial at Patna, now lost/unknown. Picture courtesy: Prof. S.R. Sarma)

On his visit to Patna in October 1991, Prof. Sarma was shown a sundial on the roof of Khanqah Emadia, a sufi seminary and place of worship. He writes, “In Patna, there is a Sufi seminary named Khanqah Emadia. Sometimes in the second half of the twentieth century, the head of the Khanqah, Shah Faridul Haque Emadi, designed an elegant sundial and had it set up on the roof of the mosque. The dial was engraved with hour lines and two long curves to indicate the times of the midday prayer *zuhr* and the afternoon prayer ‘*asr*. I saw it and photographed it in 1991. In the course of repairs, subsequently, the sundial was removed and discarded in a store room; I understand that the dial plate is still intact, but the gnomon is lost.” The dial was engraved on an octagonal metal plate with each side measuring 152 mm. An elegant brass gnomon rose from it at an angle equal to the latitude of the city of Patna, that is 26° .

A small vertical pin having pointed tip, with unknown intended use, stood from the surface of the hypotenuse. The hour lines were marked from 5 am to 7 pm in common Arabic/Persian numerals. The curves for *zuhr* and ‘*asr* were drawn so ingeniously that they themselves appeared as the words *zuhr* and ‘*asr* respectively.

The north point was labelled as *Allah*. On the east point was written *al-mashriq* and on the north point, *al-maghrib*. On the left half of the dial was engraved the 38th verse of the 36th chapter of the Qur'an: "And the Sun runs his course for a period determined for him: that is the decree of (Him), the Exalted in Might, the All-Knowing."

My attempts to locate it and take fresh photographs through my colleague was unsuccessful. He visited the Khanqah and met the caretakers there, but none could tell for certainty where exactly we could find whatever remained of the unique dial. Therefore, Prof. Sarma's photo is the only document to show the sundial in full.

After getting to know of these three sundials of different periods in different parts of India, my interest was further aroused. I began to search for more sundials and could locate the following specimens.

4. Chinna Pallivassal Mosque at Pulicat

Pulicat (13.42° N 80.32°E) is a sea-side town that straddles across the border of Andhra Pradesh and Tamil Nadu at around 70-kms north of Chennai. It is famous for India's second largest brackish water lake or lagoon after the Chilka Lake. It also boasts of a rich cultural history, beginning with the Chola Dynasty. In the 14th century, it came under the Vijayanagar empire and in the 16th century, the Portuguese made it a base followed by the Dutch in the 18th and the British in the 19th century. All along, it has been influenced by the steady presence of a sizeable Muslim population.

The Chinna Pallivasal Mosque in this town was set up in 1708 A.D. and one of the most interesting features of this small mosque is a sundial which is still in excellent condition. When I found out this, I requested my colleague Premnath M.S. if he could visit Pulicat to fetch me details of the sundial. One Sunday morning, Premnath rode his bike all the way from Chennai and I had an excellent set of clear images of the sundial.

The sundial has clear inscriptions which say that it was set up in 1334 Hijri, or 1914 A. D. at the instance of Haji Mohammad Hussain Sahib of Muthialpet, Chennai. It is mentioned that it was made by Muhammad Abdullah Ahkar and verified by Haji Mehmood Sahib.



(The Pulicat Sundial showing two 'asr' prayer lines on top right. Photo courtesy: Premnath M.S.)

The dial plate measures 25 x 20-cm, upon which a triangular gnomon is affixed. The left side on the scale starts from 6 am marked on the horizontal line and shows the morning hours of 7 am, 8 am, 9 am, 10 am and 11 am. The triangular gnomon marks the 12 noon and thereafter the semi-circular dial is marked with afternoon hours of 1 pm, 2 pm, 3 pm, 4 pm, 5 pm and 6 pm. The hours between 7 am to 7 pm are further divided in 15 minute intervals. The gnomon has a finite width (as opposed to a thin sheet of blade), and in designing it, a double-line has been used, called a substyle. After drawing the substyle with the gnomon's width, the semi-circular sundial's design must have been cut out and pasted on both sides of it to complete the plan. The horizontal co-ordinates in such a dial is always 6 am and 6 pm.

Two broad curves above the right-hand side of the semi-circular dial shows the beginning and end times for mid-afternoon prayer 'asr. The first line is labelled as 'asr *awwal shafi* meaning the first time-limit of the 'asr according to the Shafi school of jurisprudence. The second curve is marked as 'asr *sani hanifi*, meaning the second time-limit of the 'asr according to the Hanifi school of jurisprudence.

Like the 'asr curves of Hyderabad and Srirangapatna which we will see in following section, the Pulicat 'asr prayer curves are two broad wings joined at a sharp angle midway. The shadow of the gnomon for the first 'asr curve follows the rule $s = n + g$, calculated from winter solstice to summer solstice. The sharp point denotes the equinox where the shadow length is zero at midday.

The dial stands out for its simple lines and clarity of engravings, thanks to the good maintenance.

5-6. Srirangapatna, Juma Masjid & Gumbad,

Around 130 kilometres from Bangalore and 15 kilometres from Mysore lies the town of Srirangapatna, erstwhile capital of Mysore under Hyder Ali and Tipu Sultan. And here in this historical town, we discovered the next two gems in our search for sundials in Indian mosques. Ejaz

Ahmed, my colleague from Bangalore readily agreed to explore the town on a weekend, and together with his friend, managed to travel there and sent me detailed pictures and measurements of these two sundials.



(Tipu Sultan's sundial with concentric circles atop the Jamia Masjid, Srirangapatna, Mysore. Photo courtesy: Ejaz Ahmed.)



Faint traces of two 'asr' curves on the Mysore Jamia Masjid sundial. Photo courtesy: Ejaz Ahmed)

The first sundial is situated on the terrace of the Jumma Masjid that was built by Tipu Sultan in 1782 and originally called Masjid-e-Ala. The dial is circular in shape with a diameter of 53.34 cm set up on top of a 2-metre tall pillar.

The dial is engraved with 19 concentric circles that are criss-crossed by four diameter lines. Its design is unlike anything we have encountered so far. There are quarter circles in Delhi and Hyderabad dials, but Tipu's dial has the circles drawn in full. Out of the four diameters, two must have indicated the cardinal directions. The centre has a hole where the gnomon was hosted. A thick line radiates from the centre.

Two parallel broad sweeps of arcs are very faintly visible on top left of the image, similar to the 'asr' curves elsewhere. Concentric circles were used to measure the length of the shadow. Inscriptions in small boxes along the circumference are placed at the end of the straight lines. There seem to be some other inscriptions, unfortunately, none of these can be deciphered as the dial surface is severely eroded. It is sad that these important historical artefacts set up by Tipu Sultan are in such a critical condition.

The second sundial is near the Gumbad, the mausoleum of Tipu Sultan and his parents Hyder Ali and Fakr-Un-Nisa. The dial here is engraved on a rectangular slab of black stone measuring 63.5 x 48.3 cm set up on a 94-cm high rectangular pillar. The design of the sundial is exactly similar to at the mosque. The condition is equally bad to elicit any meaningful conclusions from its inscriptions.

The rest of the sundials which we discovered were meant only to show the regular time of the day, but they did not have any 'asr' curves. These dials are described in the order in which they became known to us.



(The second sundial of Tipu Sultan near the Gumbad in Srirangapatna based on same design of concentric circles. Photo courtesy: Ejaz Ahmed)

7. Moti Masjid, Agra

For unfathomable reasons, visitors are not allowed in the Moti Masjid in the Agra Red Fort as well as in the Moti Masjid of Delhi Red Fort. The Delhi Moti Masjid was constructed by Aurangzeb while the Agra Moti Masjid was by Shah Jahan. Out of these two contemporary mosques, only the Agra Masjid has a sundial in its courtyard while there is no such dial in the Delhi Red Fort mosque. It therefore raises the question if the dial was originally installed in the mosque courtyard at Agra Fort or was later relocated there.

Capt. J. T. Boileau, of the Bengal Engineers, was the first to describe the sundial at Agra. His report was published in *The Journal of Asiatic Society of Bengal*, volume 2, edited by none other than its famed secretary James Prinsep in 1833.

Boileau writes, “Among the curiosities of this once great emporium of learning and art, which have attracted the attention of strangers, is a dial-plate of white marble, with lines inlaid on its surface of a black slate... The style, which appears to have been an upright round pin, is gone, and the inlaying has been pulled out; but the configuration of the lines is still perfect, being marked by the channels wherein the inlaying fitted.”

He says that there were no hour lines except the meridian marking of XII and the ends of the dial marked with VI am and VI pm, which is obvious as the dial’s use was for regulating prayer times only.

He then makes two interesting observations:

- The dial surface is inclined to the south by $3/8^{\text{th}}$ of an inch, making him wonder if the sundial was originally installed elsewhere and the inclination could be the result of bad workmanship while re-installing at the present location. Says he, “...which leads me to believe, that it has been removed from the place where it was originally fixed; for the inclination is too small to affect the projection of the shadow of the gnomon in any sensible degree, and I believe, therefore, that it stood originally in a perfectly horizontal position.”
- He noticed an inexplicable wide arc and absence of prayer lines, “...but the object of the circular arc, which subtends an angle of about 95 degrees, has never been explained, although many celebrated Moulavis have visited the Masjid and examined the dial as it stands.”

We then scoured old accounts to get other perspectives of this elusive dial. In Alexander Cunningham’s ASI report 1871-72, his assistant A.C.L. Carlleyle describes the sundial as “an ancient sundial composed of a low octagonal marble pillar about 4 feet in height with no gnomon but simply two cross lines and an arc.” His description is repeated verbatim by John Murray in his 1911 book “A Handbook for Travellers in India, Burma and Ceylon”. Photographer Samuel Bourne passingly remarks in his photograph titled ‘Interior of the Motee Musjid, Agra’ taken in 1865 and now with the British Library (Photo 11/54, item number 1154) that “The central courtyard contains a square marble tank and a sundial in the shape of an octagonal marble pillar”. In recent times, Salim Ansari in his paper “Moti Masjid: A Real Pearl in Agra Fort” in ‘Proceedings of the Indian History Congress, Vol 73 (2012)’ provides a black-and-white image which is not very clear.

In the unfortunate restriction of access to the dial and lack of information elsewhere, we need to return to Captain Boileau who is the only person in last almost 200 years to write on the artefact.

Until further examination is done, this sundial remains an enigma with the only account by Boileau suggesting that its lines could not be fully deciphered by many Muslim scholars of his time.

8. Khanqah of Hazrat Maulana Ziauddin Saheb, Jaipur

We encounter the next sundial in the Khanqah of the 18th century Sufi saint Hazrat Maulana Ziauddin at Jaipur. He was born at Delhi in 1730 but later migrated and settled at Jaipur and was popularly addressed as ‘Maulana Sahib’. He came when the city was ruled by Sawai Pratap Singh (r. 1778-1803), grandson of Sawai Jai Singh, particularly remembered as the builder of Hawa Mahal. The king was deeply impressed with the miraculous powers of Maulana Sahib and became a devotee of the Sufi saint. He also allowed the saint to construct many mosques in the city. The Sufi convent or Khanqah was Maulana Sahib’s spiritual abode where he initiated his followers in various Sufi Orders. He spent his life in spiritual quest in this Khanqah till his demise in 1816. By conjecture, we can say that the sundial present here was constructed during the reign of Pratap Singh, that is, between 1778 to 1803.

The sundial is set up on the Khanqah's terrace, which is not accessible to be public. We are grateful to Syed Ziauddin Ziai, the spiritual successor of the Saint and hereditary administrator of the dargah who has kindly informed us about the sundial and provided us with its photographs. I had first met him in 2015 during a Sufi Trail led by author Sadia Dehvi organised by Times of India. Since then I was fortunate enough to keep in touch with him and received much help from him on researching for an earlier blog. When I casually mentioned him that sundials as my latest topic of interest, he readily provided the valuable information. I think, this is the first study of this sundial done so far.

The dial is mounted on a short pillar and a triangular gnomon stands atop the perfectly round disc of sundial. The gnomon's angle with respect to the horizontal plate must be about 27 degrees, the altitude of the city of Jaipur. Interestingly, like the sundial at the Mecca Masjid at Hyderabad, this dial is also marked with the traditional Indian *ghatis* of 24 minutes and not in 60 minute hours. But here there are 17 *ghatis* on either side of the gnomon. No prayer lines are drawn, in fact there are entirely no inscriptions on the dial. This sundial seems to be the oldest Islamic sundial at its original position with its gnomon intact.



(The unusual sundial on the terrace of Maulana Saheb's Khanqah at Jaipur showing measurements in traditional 24-minute ghati. Photo courtesy: Syed Ziauddin Ziai, Gaddi Nasheen of Maulana Saheb's mosque and Khanqah)

The dhoop-ghadi at Delhi's Jama Masjid has the hours marked in hours of 60 minutes.

The horizontal line perpendicular to the triangular gnomon is the horizon line from East to West, marking the sunrise and sunset respectively. Two more lines radiate below the horizontal line on both sides, indicating that the counting started two *ghatis* before sunrise and ended at two *ghatis* after sunset.

On careful observation of this dial, we find two faint crosses marked at two points on its rim, intended purpose of which is unknown. Counting from the horizontal line, the x-marks are at the 7th *ghati* from sunrise and sunset, i.e. 2 hrs 48 minutes after sunrise and 2 hrs 48 minutes before sunset.

9. Aastana Masjid, Ghazipur

Ghazipur in eastern UP, also known also as Ghauspur in historical accounts, boasts of several monuments, including the tomb of Governor-General Lord Cornwallis who died here in 1805, a forty-pillared hall or 'Chihil Sutun' built by the eighteenth century Mughal governor Abdullah Khan, an opium factory built by the British in 1820, and the Aastana Masjid and Khanqah of the Sufi saint Hazrat Syed Shah Junaid.



(Dhoop ghadi on the terrace of Aastana Masjid, Ghazipur, overlooking the Ganges. Photo courtesy: Dr. Nadeem Adhami)

Syed Shah Junaid (1520 – 1581) was the son of an influential noble man of Sultan Ibrahim Lodi of Delhi and enjoyed a lavish childhood. Afterwards he denounced the worldly luxuries and chose to follow the spiritual path and went abroad to Baghdad. There he got the status of '*khilafat*' or spiritual successor from Saiyid Abdul Qadir Al-Jilani, who had established the Qadriya Order of Sufism in Iraq. He came back to India and established the Khanqah and mosque at Miyanpur in Ghazipur (25°34'36"N 83°34'55"E). His tomb or dargah is at the same place. It is here that we discovered our next sundial.



(The well-maintained Dhoop ghadi on the terrace of Aastana Masjid, Ghazipur, overlooking the Ganges. Photo courtesy: Dr. Nadeem Adhami)

When I learnt of this dial, I was looking for friends who could visit the mosque and help me with its photographs and details. I am grateful to Dr. Nadeem Adhami, Director of Shah Faiz Public School at Ghazipur whom I contacted after getting his details on internet. He quickly provided me with a fine set of images. My colleague Gurdeep Singh could arrange detailed measurements of the dial. These were enough to study the dial.

The octagonal sundial is mounted on a short pillar on the terrace overlooking the river Ganga. The thick slab of the pillar top makes the dial plate. The East-West line marks the sunrise and sunset while hour lines are highlighted in white. The gnomon and the dial surface are brightly painted in red and green. There are no inscriptions or labels and hours are not further subdivided.

The 76.5 cm high pillar is shaped like a flower vase, at the top of which is the dial plate of 5.5 cm width, each side measuring 25 cm. The E-W horizon line measures almost the same as the N-S polar axis, both about 55 cm. The green coloured gnomon measures 23 cm as its base and 11 cm as its height, thus giving an angle as $\tan(x) = 11/23 = 0.478$, or $x = \arctan(0.478) = 25^{\circ}55'$ which is the altitude for Ghazipur.

Boats can be seen anchored on the mighty Ganges below. A bench is thoughtfully provided for the observer to sit.

10. Nauli Sharif, Nauli

About 25 kilometres from the city of Ghazipur lies Nauli ($25^{\circ}29'33''\text{N}$ $83^{\circ}42'48''\text{E}$) where we find our next sundial at the Mazar of Ayyube Ali Shah, popularly known as Nauli Sharif. It is an interesting dial. My thanks once again to my colleague Gurdeep Singh, who could arrange its images and measurements.

The dial plate measures 75-cm along the horizon line that forms the base of the semi-circular dial and 65-cm in width. Its triangular gnomon is freshly painted in red with few drops of colour dripped on the dial plate. The hypotenuse of the gnomon measures 20-cm and it has a vertical projection of 9-cm. The dial has hour lines from 6 am to 6 pm while the hours from 7 am to 5 pm are marked in 15 minute divisions. The hour marks on both sides of the noon mark are prominently labelled, signifying its main use for regulating prayer times.

A line of inscription at the bottom has faded and can no longer be deciphered. Probably an attempt can be made to decode it by putting a paper on the surface, and rubbing it with fine charcoal or pencil.



(Nauli Sharif sundial, Ghazipur. Photo courtesy: Gurdeep Singh)



(Undecipherable inscriptions on Nauli Sharif sundial, Ghazipur.)



(The dhoop-ghadi in front of the Nauli Sharif, Ghazipur. Photo courtesy: Gurdeep Singh)

11-12. Fatehpuri Masjid, Delhi

After exploring the span of the entire country, we decided to have another look at the various monuments in Delhi itself. Despite our best efforts, we found no sundials: neither in the Lodi Gardens, Safdarjung Tomb, Firoz Shah Kotla, nor in the Dargah of Nizamuddin Auliya, Humayun's Tomb, the Chilla or Khanqah of Nizamuddin Auliya. We scoured the lanes of Old Delhi, exploring old mosques such as Mubarak Begum Masjid as well as both the Sunheri Masjids – one on Chandni Chowk and another near the Delhi Gate of Red Fort, all without success. But to our utter surprise, we found two interesting items in the Fatehpuri Masjid. Starting from the Jama Masjid of Delhi, we returned to the Fatehpuri Masjid, making a full circle like the hands on the dial of a clock.



(A vertical sundial mounted on the electric pole and a horizontal sundial kept below, at Fatehpuri Masjid, Delhi.)

The history of Fatehpuri Masjid is the history of Shahjahanabad itself. It was built in 1650 by one of Shah Jahan's wives Fatehpuri Begum, so named because she hailed from Fatehpur Sikri. Standing at the end of Chandni Chowk, it stares back at the majestic Red Fort on the opposite side of the moonlit street of yesteryears, symbolising the status and power of royal women in the Mughal societal hierarchy. After 1857, the British sold off the mosque to a private merchant Lala Chunamal under whose custody it remained for 17 years. And, in the courtyard of this famed mosque we found two very remarkable *dhoop ghadis*.

At the centre of the courtyard is the ablution tank or *hauzi*, in the unusual shape of a circle in the middle and two long strips on each side, akin to a wrist-watch with a band. Around this clean tank where fishes swim unhindered, many small octagonal marble seats lie scattered for the devotees to sit and wash themselves before offering their prayers. Among these marble 'stools', on the side facing the mosque, lies an ancient sundial tossed in a similar manner.

It is a circular sundial made of marble, with a diameter of 30 cm. It is embedded in a circular sandstone slab with a diameter of 60 cm and a thickness of 13 cm. A line marking the true north is inscribed on the stone itself and extends onto the marble sundial, along the marks of the now-missing gnomon. There are no inscriptions, nor the hours are marked. The dial is from 6 am to 6 pm with the hours divided with two concentric bands. The inner-most band divides the hours into 15 minute intervals, whereas the outer band slices it further in 5 minute divisions. The gnomon must have had an appreciable thickness, for a small band is reserved in the centre of the two concentric rings.

The second sundial can easily be equally overlooked. Bolted to an electric pole, it is a south-facing vertical sundial. Its rectangular black dial plate is a sheet of 35 x 35 cm hung at a height of 240 cm from the ground to its lower side. It has a triangular gnomon at 28 cm from the bottom of the plate, around which the hour lines radiate down to cut a semi-circular ring that marks sunrise (6 am) to sunset (6 pm). In fact, this is the first instance that we have encountered a vertical sundial in a mosque.



(Horizontal sundial at Fetehpuri Masjid.)

A vertical sundial has two distinct features:

-Morning hours (6,7,8,9,10,11) are plotted on right and afternoon hours (1,2,3,4,5,6) on the left of the noon-mark (opposite to a horizontal dial)



(The only vertical Islamic sundial found in India so far – at Fatehpuri Masjid.)

'Delhi me dhoop ghadi ka waqt standard times se peeche rahta hai. Iski tafseel naqsha zel me mula khat karein ke angrezi ki kisi mah ki kisi tarikh me kitne minute peeche hota hai. Naqsha me hali qalam se minute ka hindsa hai, aur khafi qalam se satar se upar mahine ka, aur neecha tarikh ka. DHOOP GHADI MASJID FATEHPURI. DEHLI.'

-Hour lines in a vertical dial are calculated using the same formulae but using the co-latitude. Since Delhi's latitude is 28.7 degrees, calculation of a vertical sundial should be made for (90-28.7) or 61.3 degrees.

An Urdu inscription at the top of the dial reads as follows, essentially meaning that since Delhi's time lags behind the standard time, a correction must be added to the sundial's readings whose values can be referred from the table below.

According to the Shahi Imam Dr. Mufti M. Mukarram Ahmed, both these sundials were the labours of love of his late grand-father Mufti Muhammad Mazharallah (d.1966) whose scientific, religious and spiritual knowledge was unparalleled. He was a courageous man who refused to leave the mosque during the disturbances in the aftermath of partition. Authorities such as the Nawab of Hyderabad Mir Usman Ali Khan (d.1384/1967) and government officials both in the pre-partition British Government and post-partition Indian government extended invitations to felicitate him, but he never showed much interest in official engagements.



(Table on the sundial showing time offsets to be added to the dial reading to get the IST.)

33	1 3 28	1 3 24	1 4 6 8 19	4 6 9 12 14	9	12	9 10 11 4	
	24 4	9 23	1 5 29 22	26 3 8 21	22	11	7 28	
34	1 3 29	1 3 25	1 4 7 8 20	4 6 9 12 15	9	12	10 12 5 10 11	
	28 3	13 19	3 1 4 17	21 10 5 23	19	13	4 1 27 10	
35	2 2 30	1 3 26	1 3 7 8 21	4 6 9 12 16	9	12	10 12 6 10 11	
	3 19	14 16	5 19 10 12	16 12 1 28	17	15	1 4 30 17	
35	2 2 31	1 3 27	1 3 7 8 22	4 6 8 12 17	5 9	12	9 12 7 10 11	
	4 12	17 12	7 26 18 4	12 19 30 27	17	15 14	17 28 6 15 10	
35		1 3 28		7 23	4 6 8 12 18	5 5 9 12	9 12 8 10 11	
		21 8		27	8 21 26 30	2 7 11 19	13 25 9 11 23	

(The decoded table, yellow highlighted numbers denote minutes to be added to the sundial's reading to get the IST, Reds denote months, and Greens denote Dates. For example, the first entry means 33 minutes need to be added on Jan 24 and March 4. Transliteration of Urdu numerals by courtesy of Basharat Khan)

On the scientific front, he always pondered over the relativity of local time and the standard time and devised various calculations to regulate prayer times. He made a universal table that shows the eight prayer times irrespective of the year. It is framed and hung near the mihrab. He seemed to have designed the vertical dial after drafting the table. Regarding the circular dial, the Shahi Imam fondly remembers that it was originally installed on top of a small pillar at the centre of a small tank or 'hauzi' that no longer exists. He said that there was a third sundial designed by his grandfather which no longer survives. The grave of Mufti Muhammad Mazharallah is located inside the courtyard of Fatehpuri Masjid.

A Brief History of Sundials

The oldest sundial extant today is believed to be an artefact in the Berlin Museum that dates to 1500 B.C. It is believed that the sundial was introduced in Greece by astronomer Anaximander around 600 B.C. Roman dramatist Plautus who died about 184 B.C. lamented that a wretch had chopped his days into pieces by installing a sundial in the market place. Probably at that time, loud announcements were made at each hour boundary. Plautus says,

“The gods confound the man who first found out

How to distinguish hours – confound him, too,

Who in this place set up a sun-dial,
 To rub and hack my days so wretchedly
 Into small pieces! When I was a boy,
 My belly was my sun-dial – one more sure,
 Truer, and more exact than any of them.
 The Dial told me when 'twas proper time
 To go to dinner, when I had aught to eat;
 But, now-a-days, why even when I have,
 I can't fall to, unless the sun gives leave.
 The town's so full of these confounded dials,
 The greatest part of its inhabitants,
 Shrunk up with hunger, creep along the street."

The scientific knowledge was passed on from Greeks to Romans and then to Muslims. Muslims came into contact with the Greco-Romans in 7th century A.D. and transformed the entire science of gnomonics to suit their religious requirements. It was a happy coincidence of religion and science. The Umayyad Caliph 'Umar 'ibn 'Abd al-Aziz of Damascus was known to have used a sundial around 700 A.D. and in the 8th century we know of al-Fazari and Ya'qub ibn Tariq who worked on the science of shadows, though they did not write any books or treatises. From the 9th century, we come across a steady flow of Muslim astronomers who wrote books and almanacs, calculated tables for regulating prayer times using complex computational and graphical methods. It was then that the use of sundial was first used to predict prayer times.

Al-Khwarizmi of 9th century Baghdad is credited with the first known astronomical tables to construct horizontal sundials. Baghdad was the centre of such innovations till the 10th century, producing at least seven known early Islamic astronomers. Then it was followed by Cairo, Yemen, Damascus and Istanbul in subsequent centuries. Ibn al-Shatir from 14th century Damascus is believed to be the father of 'polar horizontal sundial' where the gnomon is oriented to North. His iconic huge sundial complex on a 2 x 1-m plate in Damascus made in 1371/2 A.D. is the most well-known sundial, which was broken during restoration and was replaced with an exact replica in 1876 A.D. by al-Tantawi. His design of 'polar horizontal sundial' then spread eastward to India and westward to Europe. In Europe, it became a popular garden decoration, and in India it was absorbed in Sanskrit astronomy and was called the '*palabha-yantra*'.

These scholars devised formulae that could be used to predict prayer times, calculate the time since sunrise, the hour-angles, hour-angles at the afternoon prayer time '*asr*' and so on. Tables were published so that sundials could be constructed anywhere in any mosque just by referring these tables, without the need for complex calculations. Tables were provided for every type of requirement in a mosque, such as, when the muezzin should call for prayer, how much time the faithful still had till the muezzin would call, what time the lamps on minarets during Ramazan were to be extinguished, etc. Calculations were done for each degree of longitude for duration of daytime, duration of night time, start and end of the '*asr*' and so on.

Before the 13th century, the muezzin in a mosque was given the responsibility of timekeeping apart from his usual duty of announcing the prayer times. Although he was chosen mainly for the quality of his voice and knowledge of religious rituals, he was also required to know the basics of ‘folk-astronomy’, the times of daytime prayers, shadow lengths at *zuhr* and *‘asr* and so on. From the 13th century onwards, a new class of professional astronomers were attached to mosques for scientific regulation of time and were called ‘*muwaqqit*’.

Conclusion

Here is the list of sundials presented in the study, arranged as per their locations from north to south

Instrument	Mosque	Date of installation	Access	Condition
Horizontal Sundial	Jama Masjid, Delhi	1819-20	Open to public	Inscriptions badly effaced
World Map	Jama Masjid, Delhi	1831-32	Open to public	Inscriptions badly effaced
Horizontal Sundial	Mecca Masjid, Hyderabad	1693	Open to public	Inscriptions very badly effaced
Horizontal Sundial	Khanqah Emadia, Patna	Mid 19th C	No longer exists	lost/destroyed
Horizontal Sundial	Chinna Pallivasal Mosque, Pulicat, TN	1915	Open to public	Excellent
Horizontal Sundial	Juma Masjid, Srirangapatna, Mysore	1782	Open to public	Inscriptions critically effaced
Horizontal Sundial	Gumbad, Srirangapatna, Mysore	1782	Open to public	Inscriptions critically effaced
Horizontal Sundial	Moti Masjid, Agra Fort	1673 (possibly relocated later)	Access to Mosque Restricted	Not Known
Horizontal Sundial	Khankah of Moulana Ziauddin Saheb, Jaipur	1786 - 1803 (conjectured)	Access to the terrace Restricted	Good
Horizontal Sundial	Aastana Masjid, Ghazipur, U.P.	?	Open to public	Excellent
Horizontal Sundial	Nauli Sharif, Nauli, U.P.	?	Open to public	Excellent
Horizontal Sundial	Fatehpuri Masjid, Delhi	~1950	Open to public	Good
Vertical Sundial	Fatehpuri Masjid, Delhi	~1950	Open to public	Good

This is a brief survey of this highly interesting topic. But it can hardly be termed as comprehensive, considering that there may be many more such sundials in the country – known as well as un-noticed. **I would be grateful if you discover any other such sundials in Islamic places of worship and share the details so that the short survey initiated here can be further expanded.**

1.4 Preservation

Being exposed to all kinds of weather in open air, these ‘dhoop-ghadis’ suffer extensive corrosion of stone inscriptions. Conservation initiatives such as putting glass cases above them, or retiring them to museums while re-constructing exact replicas on fresh marble or stone slabs with steel or brass fittings at their original positions will trigger public interest in this lost science.

It is important to locate and preserve these scientific artefacts before they are lost in obscurity.

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